JP,06-090950,A STANDARD ZOOM-UP ROTATION No Rotation REVERSAL RELOAD

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probe | AND

AND

backing | AND

AND

low high impedance | AND

AND

Date of publication of application --- e.g.19980401 - 19980405

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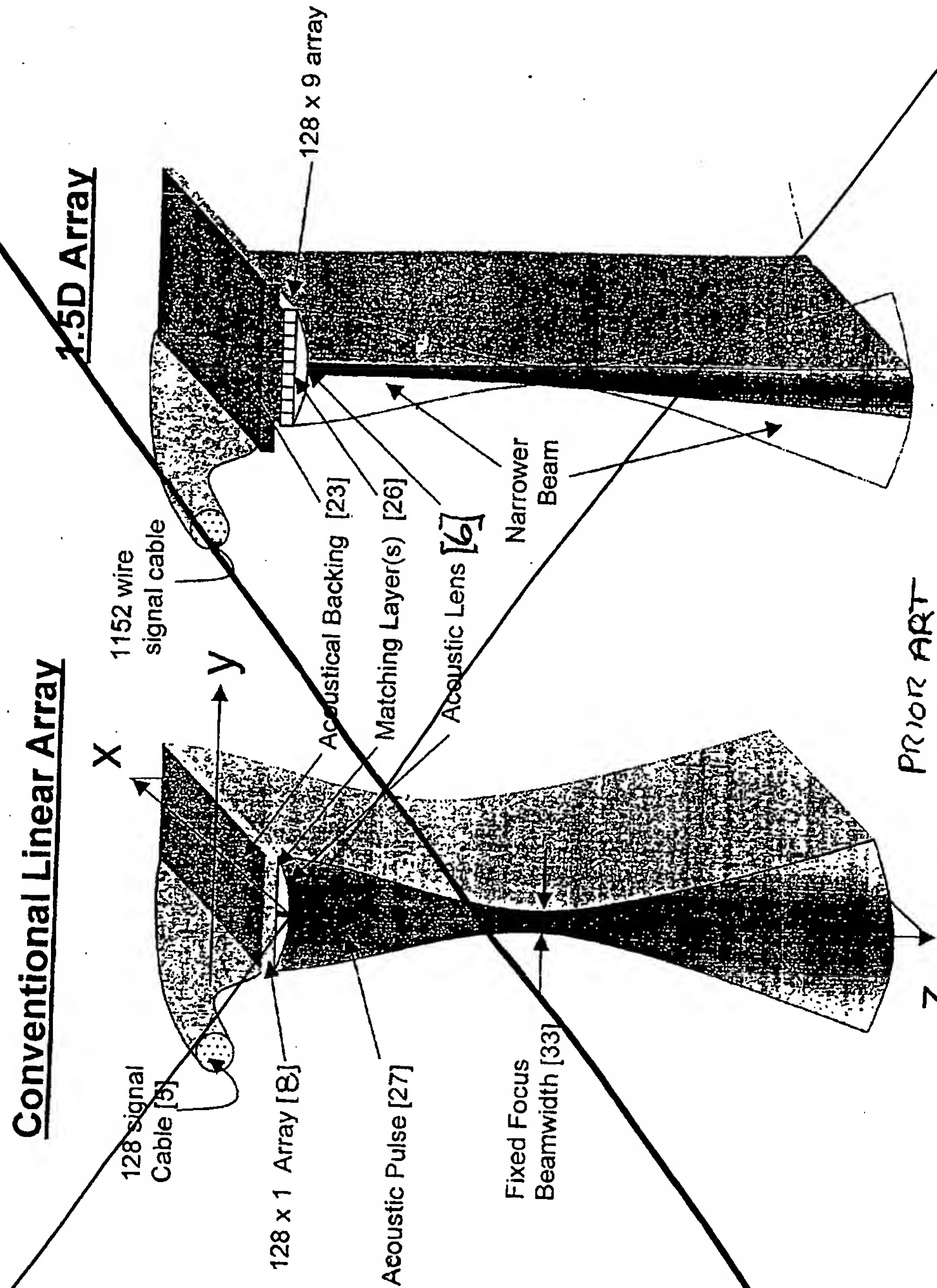

PRIOR ART
FIG. 4

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3	BRS	L3	0	"erikson-kenneth,in."	US-PGPUB	2007/10/09 06:52	
4	BRS	L4	0	"erikson-kenneth,in."	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	2007/10/09 06:52	
5	BRS	L5	0	"erikson-kenneth.in."	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	2007/10/09 06:52	

which is less than 1% of the typical value in a coaxial cable. This results in significantly less signal loss.

[0105] Referring again to the figures, as is further explained below, there are one or more integrated circuits in probe [320] between the array transducers and interconnecting cable [322] to match the impedances of the transducers to the signal conductors in the cable. Dramatic improvements in signal level through the coaxial signal conductors are achieved, as compared to the prior art practice. Referring back to **FIG. 3**, and using the same calculations previously described, curves [90], [92] and [94] represent the signal loss in similar arrays when used with active electronics located adjacent each transducer of the array.

[0106] Curve [90], using an integrated circuit with 750 fF stray capacitance with same 1.25 or 1.5D array as curve [84], shows a 3% signal loss at 2.5 MHz and only 20% loss at 15 MHz. Curve [92] is a similar curve for the 1.75D array and should be compared to curve [86]. Losses vary from 7% to 35% over the frequency range.

[0107] The smallest element, a 2D array as shown in curve [94], has a loss ranging from 15% at 2.5 MHz to 57% at 15 MHz. When compared to the ID array in common use today, this is a substantial improvement over the passive cable calculations represented by curves [82]-[88] as discussed previously.

[0108] Referring now to **FIG. 6** in conjunction with **FIG. 5**, there is shown the functional block diagram of the internal electrical circuits of probe interface [324]. Multi-pin connector [326] typically has 128 or more pins [325] to connect channel signal wires from beamformer [280] to probe interface [324]. Only channels 1 and 128 are shown for clarity.

[0109] Signal wire [327] is further connected to one of 128 T/R switches and to one of 128 amplifiers in electronics module [360], which is discussed in more detail below. Microcontroller [332] receives control information from ultrasound system control microprocessor [278] via control line [330]. This information would typically include vertical or horizontal probe orientation, transmitter focus range, receiver focus range, and any other necessary or useful control information. Information to setup the scanning parameters for the each entire frame would typically be transmitted in advance of the transmitter pulse or frame data acquisition.

[0110] The primary function of microcontroller [332] is to translate the scanning parameters into time delays for each of the transducer array strips, either vertical [112], **FIG. 10**, or horizontal [118], **FIG. 11**, contained in probes tiles [110], **FIG. 9**. This information is passed on to probe [320] via signal line [350]. Microcontroller [332] may also send status information such as probe type, correct probe operation, and related information, back to processor [278] via line [330].

[0111] Power supply [342] derives it power from ultrasound system [270] via wire(s) [328]. It may derive other voltages as required to power the electronics in interface [324] or in probe [320]. Bi-directional control line [350] is used to send information to, and receive status information from probe [320]. Wire [116] sends transmitter pulses to, and received signals from probe [320]. Cable [322] is a bundle of wires, typically 128+32=156 total wires. These wires are usually coaxial cables to minimize crosstalk between wires.

[0112] Referring to **FIG. 7**, electronics module [360] includes switches [361] and [364] and amplifier [370]. The function of the two switches is to isolate amplifier [370] from any high voltages coming from ultrasound system [270] that might damage the amplifier. Such high voltage pulses are typically used to generate ultrasound pulses in passive probes.

[0113] In **FIG. 7**, if switch [361] is in position as shown, in the transmission mode conducting to node [363], the transmitted pulse from the system will pass to resistors [367] and [368]. The values of these resistors are chosen to attenuate the transmitted signals from ultrasound system [270] of **FIG. 5**, to voltages that are safe for the rest of the probe electronics. This signal then serves as a synchronization pulse for the probe channel. Switch [364], when conducting with node [365] as shown, passes the transmitter synchronization pulse to probe [320] as in **FIG. 5**, via respective wires [116]. When the system is in the receiving mode, switches [361] and [364] are switched to nodes [362] and [366], respectively. This allows returning signals to be routed through amplifier [370], back through conductor [327], and pin [325] into beamformer [280].

[0114] Referring to **FIG. 8**, there is illustrated the functional block diagram of the supporting electronics inside probe [320]. Time delays for each strip array of transducers and each tile of strip arrays, as explained below and illustrated in **FIGS. 9, 10**, and **11**, plus any other signals, come into to microcontroller [380] via bi-directional path [350]. Microcontroller [380] interprets the time-delay data and places it into look-up table [381] via signal line [382]. This look-up table permits rapid, easy access.

[0115] Transmitter delays may be sent to respective integrated circuits [32], there being one closely connected or integrated into each tile array of transducers and to the individual transducers of the tile, over signal line [181]. Similarly, receiver delays may be sent over signal line [168]. These delays, which must change in real-time as the pulse propagates into the subject under test, are typically loaded into a memory buffer in integrated circuit [32].

[0116] As has been discussed earlier, flip chip mounting and electrode bump bonding techniques and related advances in chip fabrication, already in commercial use and still evolving, permit the close connection or integration of transducers and transducer arrays of various types with directly supporting power, control logic and data circuitry such that individual transducers and desirable groups of transducers can be "pre-wired" at the chip level, thereby shifting a significant portion of the system circuitry closer to the transducer array than was possible only a short time ago.

[0117] Vertical or horizontal selection inputs may be sent to IC [32] via control line [53] from the control console and interface box. Transmitting or receiving is selected in IC [32] by means of control line [157]. Electrical power for these probe electronics is delivered by wire(s) [344] to probe power conditioner [345] which may consists of voltage regulators or the like. This conditioned power is sent to microcontroller [380] via wire [347], to look-up table [381] via wire [347] and to IC [32] via wire [346].

[0118] **FIG. 9** is a top-view diagram of one aspect and embodiment of the invention, depicting an orthogonally reconfigurable, integrated matrix, acoustical transducer

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8	BRS	L8	132	l7 and backing	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	2007/10/09 06:56	

lines to enable real time reconfiguration of the matrix array between vertical and horizontal modes of operation.

[0184] The multiplicity of tiled subarrays that make up the full matrix array may be configured as a pair of W subarray wide by L subarray long, orthogonally oriented arrays, whether overlapping or not, where W is at least 1 and preferably at least 5 subarrays wide, and L is at least 8 and preferably at least 128 subarrays long. Where the orthogonal arrays are overlapping, they share common subarrays at the area of overlap.

[0185] There may be an orthogonally switchable matrix array transducer according to the invention, combined with a multiconductor cable and an interface box attachable to a host control system, which may include a portable computer system and suitable software. Alternatively, the host control system may be a portable or non-portable general purpose computer system and suitable software and an interface box, where the interface box includes a beam former control capability compatible with the matrix array of the probe.

[0186] Yet another example of the invention is an orthogonally switchable matrix array transducer of the general NxN transducer with supporting circuitry construction described above, where the vertical and horizontal array patterns are overlapping and sharing common subarrays at the area of overlap, but where the remaining subarrays consist of two flanking regions of fixed mode subarrays. There is a first flanking region of subarrays in which the supporting circuitry includes N vertical bus lines, each transducer is connected to a vertical bus line, N transducers to each vertical bus line, so that the subarray functions as a set of N vertical linear transducer strips for vertical mode operation. There is a second flanking region of subarrays in which the supporting circuitry includes N horizontal bus lines, each transducer connected to a horizontal bus line, N transducers to each horizontal bus line, so that each of these subarrays functions as a set of N horizontal linear transducer strips for horizontal mode operation.

[0187] This embodiment may have supporting circuitry in the form of an integrated circuit fabricated on a circuit substrate which is bonded to the transducer substrate so as to provide electrical connections to the transducers, and where the supporting circuitry in the overlapping area of common subarrays is switchable in real time between vertical and horizontal bus lines and operation so as to enable real time reconfiguration of the probe between vertical and horizontal modes of operation, while the fixed mode subarrays in the flanking regions need be selectable in real time only as between the first flanking region and the second flanking region in order to complete the scan pattern.

[0188] As another example of the invention, there is a method for performing ultrasound imaging consisting of the following steps:

[0189] (a) Using a matrix array transducer probe remotely connected to a control system, where the transducer probe consists of a multiplicity of tiled subarrays of N by N transducers, where the subarrays are oriented in a pattern having a vertical component overlapping a horizontal component, and where the subarrays are selectable as either the vertical component combination or the horizontal component combination of subarrays. Each subarray is switchable between a first operating mode of horizontal linear transducer strip arrays and a second operating mode of vertical linear strip arrays, the output of the linear strip arrays of each tiled subarray being sumable by supporting circuitry within the transducer probe as a single output signal, N being equal or greater than 2, and the output signals being communicated to the control system.

[0190] (b) Command and record a first ultrasound image in the first mode;

[0191] (c) Switch the transducer probe operation between the first mode and the second mode; and

[0192] (d) Command and record a second ultrasound image in the second mode.

[0193] There may be a further step:

[0194] (e) Integrate the first ultrasound image with the second ultrasound image so as emulate two-dimensional ultrasound operation, and produce real time, three-dimensional imagery.

[0195] As still yet another example, there is a method for performing ultrasound imaging consisting of the steps:

[0196] (a) First, use a matrix array transducer probe remotely connected to a control system, where the transducer probe consists of a multiplicity of tiled subarrays of N by N transducers, with the subarrays oriented in a pattern having a vertical component and a horizontal component with an area of overlap. There is a first flanking region associated with the vertical component of the pattern, and a second flanking region associated with the horizontal component. The subarrays of the first flanking region are configured as N horizontal linear strip arrays, and the subarrays of the second flanking region are configured as N vertical strip arrays. The subarrays of the flanking regions selectable in real time between first and second flanking region, while the subarrays in the area of overlap are bi-modal subarrays switchable between a first operating mode of horizontal linear transducer strip arrays and a second operating mode of vertical linear strip arrays, the output of said linear strip arrays of each said subarray being summable by supporting circuitry within the transducer probe as a single output signal, N being equal or greater than 2. The dual switching capability permits real time cross axis operation of the scanner system, emulating a full two dimensional scanner capability with fewer transducers and fewer cable conductors than would otherwise be required. The output signals are communicable to said control system.

[0197] (b) Command and record a first ultrasound image in the first operating mode.

[0198] (c) Switch between flanking region subarrays, and switch the orientation of the subarrays in the overlapping area between the first operating mode and the second operating mode.

[0199] (d) Command and record a second ultrasound image in the second mode.

[0200] The steps of switching between modes may occur in real time, so as to permit real time imaging or imaging at

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10	IS&R	L10	1	("6524254").PN.	USPAT	2007/10/09 07:58	
11	BRS	L11	1	"20030018260"	US-PGPUB	2007/10/09 08:13	
12	BRS	L12	1	"20030018267"	US-PGPUB	2007/10/09 08:13	
13	IS&R	L13	659	(310/322).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	2007/10/09 08:58	

line, N transducers to each said vertical bus line, said subarray functioning as a set of N vertical linear transducer strips for horizontal mode operation, N being at least 2 and preferrably 8,

a second flanking region of subarrays in which said supporting circuitry includes N said horizontal bus lines, each said transducer being connected to a said horizontal bus line, N transducers to each said horizontal bus line, said subarray functioning as a set of N horizontal linear transducer strips for vertical mode operation.

16. An orthogonally switchable matrix array transducer according to claim 15, said supporting circuitry being an integrated circuit fabricated on a circuit substrate which is bonded to said transducer substrate so as to provide electrical connections to said transducers, said supporting circuitry in said common subarrays being switchable in real time between respective said vertical and horizontal bus lines so as to enable real time said reconfiguration between said horizontal and vertical modes of operation, said subarrays in said flanking regions being selectable in real time as between said first flanking region and said second flanking region.

17. An orthogonally switchable matrix array transducer for ultrasound imaging, comprising

a multiplicity of tiled planar acoustic/electronic subarrays, each subarray consisting of an N vertical by N horizontal pattern of uniformly spaced acoustical transducers fabricated on a transducer substrate and closely connected to supporting circuitry, N being at least 2 transducers and preferably 8 transducers,

said supporting circuitry comprising integrated circuits fabricated on a circuit substrate which is bonded to said transducer substrate so as to provide electrical connections to said transducers

said supporting circuitry including N vertical and N horizontal bus lines and transducer switches connected to each said transducer, each said transducer being thereby switchable between respective vertical and horizontal bus lines, all said transducer switches controlled by a bus selector switch so as to enable reconfiguration of said subarray between a set of N vertical linear transducer strips for horizontal mode operation and a set of N horizontal linear transducer strips for vertical mode operation,

said supporting circuitry further including a transmit/receive selector switch controlled by a signal line enabling said subarray to be switched between a transmit and a receiving mode, a linear transducer strip transmitter time delay circuit enabling said linear transducer strips to be relatively time shifted for transmitting, a receiver time delay circuit enabling said linear transducer strips to be time shifted for receiving, and a summer circuit for integrating the received signals of all said linear transducer strips of said subarray into a common output signal,

said supporting circuitry yet further including a multiconductor control cable for connecting said integrated circuits to an ultra sound imaging system, said imaging system thereby providing power and control inputs to each said subarray of said matrix array transducer for transmit steering, receive steering, selecting between vertical and horizontal operation, power, and clock signals, said imaging system thereby also accepting a received said output signal from the said summer circuit of each respective said subarray,

said transducer being switchable in real time between said vertical and horizontal modes of operation.

18. An orthogonally switchable matrix array transducer according to claim 17, said multiplicity of tiled subarrays configured as a pair of W subarray wide by L subarray long, orthogonally oriented arrays, W being at least 2 and preferably at least 5 subarrays, L being at least 4 and preferably at least 16 subarrays, said arrays overlapping and sharing common subarrays at the area of overlap.

19. An orthogonally switchable matrix array transducer according to claim 17, further comprising a multiconductor cable and an interface box attachable to a said control system.

20. An orthogonally switchable matrix array transducer according to claim 19, said ultra sound imaging system comprising a computer system.

21. A method for performing ultrasound imaging comprising the steps:

(a) using a matrix array transducer probe remotely connected to a control system, said transducer probe consisting of a multiplicity of tiled subarrays of N by N transducers, N being at least 2, said subarrays oriented in pattern having a vertical component overlapping a horizontal component, said subarrays being selectable as between said vertical component and said horizontal component and switchable between a first operating mode of horizontal linear transducer strip arrays and a second operating mode of vertical linear strip arrays, the output of said linear strip arrays of each said tiled subarray being summable by supporting circuitry within said transducer probe as a single output signal, said output signals being communicated to said control system,

(b) commanding and recording a first ultrasound image in said first mode,

(c) switching between said first mode and said second mode,

(d) commanding and recording a second ultrasound image in said second mode.

22. A method for performing ultrasound imaging according to claim 21, comprising the further step of:

(e) integrating said first ultrasound image with said second ultrasound image so as to generate three dimensional ultrasound imagery.

23. A method for performing ultrasound imaging according to claim 22, said step of switching between said modes comprising switching in realtime.

24. A method for performing ultrasound imaging comprising the steps:

(a) using a matrix array transducer probe remotely connected to a control system, said transducer probe consisting of a multiplicity of tiled subarrays of N by N transducers, said subarrays oriented in a pattern having a vertical component and a horizontal component with an area of overlap, a first flanking region associated with said vertical component, and a second flanking

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Erikson
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(54) ORTHOGONALLY RECONFIGURABLE INTEGRATED MATRIX ACOUSTICAL ARRAY

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(57) ABSTRACT

A transducer probe has a fully populated, integrated, matrix array of acoustical transducers for ultrasound imaging, switchable in real time between two orthogonal 1.5D or 1.75D transducers arrays, consisting of tiled subarrays of transducers which may be switched in real time between vertical and horizontal strip arrays by integrated circuits directly attached to the subarrays, for performing a first level of transmit and receive beam forming functionality with either horizontal or vertical scanning. The integrated circuits include a summer circuit for reducing the output signals of each subarray to a single line, reducing the number of lines required in the cable or connection medium. An interface box mates to a host system and facilitates the switching and control function. Impedance matching in the integrated circuits between transducers and cable lines improves signal transmission in cables. Applications include medical imaging, materials testing and sonar systems.